

Trapping Social Wasps (Hymenoptera: Vespidae) with Acetic Acid and Saturated Short Chain Alcohols

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ABSTRACT Nineteen compounds were evaluated in combination with a solution of acetic acid as baits for trapping the German yellowjacket, *Vespula germanica* (F.), the western yellowjacket *Vespula pensylvanica* (Saussure), and the golden paper wasp *Polistes aurifer* Saussure. Compounds with three to six carbon chains or branched chains and with a hydroxy functional group were selected for testing based on their similarity to isobutanol. They were compared with isobutanol with acetic acid, which is a known wasp attractant. None of the compounds tested were superior to isobutanol when presented with acetic acid as a lure for these species of wasps. However, traps baited with either the S-(-)- or the racemic mixture of 2-methyl-1-butanol in combination with acetic acid captured similar numbers of both species of yellowjackets, compared with isobutanol with acetic acid. *Polistes aurifer* responded strongly to the S-(-)-enantiomer and to the racemic mixture of 2-methyl-1-butanol with acetic acid and not to the R-(+)-enantiomer with acetic acid.

KEY WORDS *Vespula*, *Polistes*, paper wasp, yellowjacket, traps, lures

ALL YELLOWJACKETS (*Vespula* and *Dolichovespula*) can be a stinging hazard, particularly in defense of their colonies; but some species come into frequent contact with people while scavenging for sugar-rich materials and animal carrion away from the nest (Akre et al. 1980). *Vespula pensylvanica* (Saussure), the western yellowjacket, is the most abundant and pestiferous native species in western North America (Duncan 1939). *Vespula germanica* (F.), the German yellowjacket, is a major palearctic pest and was accidentally introduced into a number of other geographic areas, including North America, South America, Australia, and New Zealand (Edwards 1976, Morse et al. 1977, MacDonald et al. 1980, MacDonald and Akre 1984).

Research efforts to develop control or management strategies for these and related species have focused on food baits and attractants for traps to reduce adult wasp populations or poisoned baits to reduce or eliminate wasps and larvae in nests (Grant et al. 1968, Braverman et al. 1998). Although much of this research has been conducted with food baits such as jellies or meats (Spurr 1995, 1996), synthetic chemical attractants would greatly simplify and improve the usefulness of lures, whether used in a trap or in a poisoned bait formulation. The chemical attractants heptyl butyrate and octyl butyrate are powerful attractants for the western yellowjacket (Davis et al. 1969, 1972), but do not work well for many other pestiferous species of yellowjackets (Howell et al. 1974) or other Vespidae. Recently, it was discovered that the combination of acetic acid and isobutanol is broadly attractive to a number of North American

vespid wasps, including *V. germanica*, *V. pensylvanica*, the eastern yellowjacket *Vespula maculifrons* (Buysson), the southern yellowjacket *Vespula squamosa* (Drury), and others (Landolt 1998a, 1998b; Landolt et al. 1999, Day and Jeanne 2001).

A number of chemicals were subsequently tested in comparison to isobutanol for attractiveness to *V. germanica* and *V. pensylvanica* when presented together with acetic acid. The purpose of our study was to determine if other compounds structurally similar to isobutanol can be placed with acetic acid to comprise a blend that is similarly attractive to social wasps. The hypothesis tested was that the response of wasps to isobutanol is not specific to that structure; that other structurally similar compounds would elicit similar responses from these species of Vespidae.

Materials and Methods

Four experiments were conducted to compare selected chemicals in combination with acetic acid as co-attractants for yellowjackets and paper wasps. All four experiments included the combination of isobutanol and acetic acid as a positive control. Trappit dome traps (Agrisense, Fresno, CA) were baited with 200 ml of 0.5% acetic acid in an aqueous drowning solution (Landolt 1998a) and 1 ml of a test chemical in a 2 ml polyethylene cap (No. 60975 d-3, Kimbel Glass, Vineland, NJ). All experiments were conducted near Moxee, WA, in Yakima County, with traps placed on fence rows, windbreak trees, or orchard trees. Polyethylene caps containing test chemicals were impaled on a push pin in the top of the inside of the trap. Traps were checked two or three times per week. The

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drowning solution in the trap consisted of 200 ml of water and 25 μ l of Palmolive dishwashing detergent (Colgate-Palmolive, New York). This solution was changed weekly and caps were not replaced within a test. Unless otherwise indicated, chemicals were purchased from Aldrich (Milwaukee, WI) and Sigma (St. Louis, MO). A randomized complete block design was used with a line of traps constituting a treatment block. Traps were then moved one position in the line-up each time they were checked. Traps were \approx 10 m apart and were placed at a height of \approx 1.5 m. When traps were checked, captured wasps were placed in labeled plastic bags for transport to the laboratory and were stored in a freezer until the species and sexes were sorted and tabulated.

In the first experiment, trap treatments were a cap with the following: nothing, with 3-methyl-1-butanol, 1-pentanol, 1-butanol, isopropanol, 2-methyl-2-propanol, S(-)-2-methyl-1-butanol, or with isobutanol. Three replicate blocks of these treatments were set up on 5 September 1997 and were maintained until the 15th of September, providing 12 replicates (three blocks and four dates).

In the second experiment, treatments were empty caps, caps with 2-methyl-2-pentanol, 2-butanol, 2-methyl-1-pentanol, neopentyl alcohol, 3-methyl-2-butanol, 2-methyl-2-butanol, 2-methyl-1-butanol, or isobutanol. All treatments were randomized within each of three blocks of traps. Traps were set up on 26 September 1997 and were maintained through 6 October, providing nine replicates (three blocks and three dates).

In the third experiment, treatments were empty caps and caps with 3-methyl-1-pentanol, 3-methyl-2-pentanol, 2-pentanol, 4-methyl-1-pentanol, 4-methyl-2-pentanol, and 3-methyl-3-pentanol, and isobutanol. All treatments were randomized within each of four blocks of traps. Traps were set up on 28 July 1998 and were maintained through 13 August, providing 20 replicates (four blocks and five dates).

Additionally, a fourth experiment was conducted specifically to evaluate the enantiomers of 2-methyl-1-butanol in comparison to a racemic blend. This experiment was conducted to determine if wasps responded stereospecifically, to one enantiomer only, of 2-methyl-1-butanol. The four treatments were an empty cap and caps with the S(-)-enantiomer, the R(+)-enantiomer, or a racemic mixture of 2-methyl-1-butanol. Four blocks of traps with the four treatments were placed in the field on 3 August 1998 and were maintained through 24 August, providing 24 replicates (four blocks and six dates).

Within each test and for each species, data were subjected to an analysis of variance (DataMost 1995). Means were separated by least significant difference (LSD) at $P < 0.05$. Numbers for male and female *P. aurifer* captured were combined for statistical analysis and queens versus workers were not differentiated for captures of *P. aurifer*. Only workers of *V. germanica* and *V. pensylvanica* were captured in traps during these studies. Data for replicates in which fewer than 10 wasps were captured in all traps of a block were

excluded from analyses. Numbers of workers of *Vespa atropilosa* (Sladen) trapped were not sufficient for statistical analysis.

The racemic mixture of 2-methyl-1-butanol (Aldrich) was analyzed by capillary gas chromatography using a chiral column to determine the enantiomeric makeup. Analysis was done on a Hewlett-Packard 5890II Plus gas chromatograph (Avondale, PA) with FID and splitless injection. It was equipped with a Cyclosil-B column from J&W Scientific (Folsom, CA). Column dimensions were 30 m by 0.25 mm i.d., with a film thickness of 0.25 μ m. Temperature programming was 35°C for 5 min, 3°C for min to 90°C, followed by a purge ramp 20°C for min to 220°C for 10 min. Column pressure was 15 psi, with helium flow at 30 cm/min. Neat material was weighed and prepared in a 30- μ g/ml solution (20 μ g/ml for the racemic sample of 2-methyl-1-butanol) in dichloromethane for analysis. Retention times were 19.51 min for R(+)- and 19.79 min for S(-)-2-methyl-1-butanol, with nearly baseline separation of the two enantiomers in the racemic mixture. The racemic sample was found to be 49.6% R(+)- and 50.4% S(-)-2-methyl-1-butanol. The S(-)-enantiomer used in field tests and as a GC standard was purchased from Aldrich. This material was >99% pure overall by GC analysis and was 99.7% enantiomerically pure. The R(+)-enantiomer was synthesized using a modification of the methods of Mori (1983) and of Mori and Takikawa (1991).

To obtain (R)-2-methyl-1-butanol with high stereoisomeric and enantiomeric purities it is essential to start with materials of high purity. Starting material for this reaction series was (S)-(+)-methyl-3-hydroxy-2-methylpropionate (99%, Aldrich). None of the reactions involved the optical center, the methyl branch on the second carbon; therefore the optical configuration was structurally unchanged throughout the series of reactions. The designation (S)- changes to (R)- due to naming conventions.

In this five-step series of reactions the original alcohol group of the starting material was derivitized to a pyranol ether form to protect the structural integrity of the last two carbons and methyl branch. This was followed by reduction of the methylpropionate group to an alcohol on the first carbon. This alcohol was converted then to a tosylate group to facilitate the addition of another carbon through a Grignard coupling reaction, increasing the chain to four carbons. In the final step the pyran protecting group was hydrolyzed back to the alcohol to form (R)-2-methyl-1-butanol.

At each step, the product was confirmed on IR and GC-MS to verify the successful completion of each reaction. IR spectra were obtained as neat films on sodium chloride plates on a Perkin Elmer FT-IR spectrophotometer (model 1605, Foster City, CA). Routine mass spectral analyses were obtained with a Hewlett-Packard 5971 mass selective detector coupled to a 5890II GC equipped with a DB-1 column (60 m by 0.25 mm i.d., .25 μ film, J&W). All synthetic procedures were carried out in oven-dried glassware and under argon when a closed system was necessary.

EM Omnisolv (EM Science, Gibbstown, NJ) solvents were used. Worked up reaction mixtures were dried on anhydrous sodium sulfate and concentrated by rotary evaporation under vacuum. Column chromatography on 3.3 by 30 cm columns of silica gel (Baker 80–100 mesh, 2% water added) was used for cleanup as indicated.

Step 1: (S)-(+)-Methyl-3-hydroxy-2-methylpropionate Tetrahydro-2 h-pyranyl Ether (THP Ether). Twenty-five grams (212 mMol) of (S)-(+)-methyl-3-hydroxy-2-methylpropionate (99%, Aldrich) was stirred overnight at room temperature with 21 gm (250 mMol) of dihydropyran (Aldrich) and 0.40 gm (2 mMol) of *p*-toluenesulfonic acid (TCI America, Portland, OR). The reaction mixture was then neutralized with an excess of NaHCO_3 . The yield was $\approx 100\%$ (47 g). Crude product was dried by passage through a column of silica gel, eluted with 300 ml of 30% dichloromethane in pentane. It was concentrated and analyzed on IR and GC-MS. IR: typical tetrahydropyranyl ether pattern from 1,470 to 1,250 cm^{-1} ; 1,730 cm^{-1} carbonyl of the ester; absence of 3,300 cm^{-1} for alcohols. Mass spectra confirmed this compound with a pyran base peak (m/z 85) and M-1 peak of m/z 201.

Step 2: (R)-2-Methyl-1,3-propanediol Mono THP Ether. Crude product (145 mMol) from step 1 was added dropwise to a cooled (0°C) solution of ether containing 120 mMol of lithium aluminum hydride (Aldrich) under argon. It was stirred for 4 h at room temperature. Reaction was quenched by addition of water, and reaction mixture was extracted with ether and concentrated in vacuo. Yield was 95% (21.5 g) and crude product oil was analyzed on IR and GC-MS. IR: 3,450 cm^{-1} (w), alcohol; absence of 1,730 cm^{-1} carbonyl, ester; and typical THP ether pattern from 1,470 to 1,250 cm^{-1} . Mass spectrum was consistent with pyranyl alcohol, and having an M-1 peak of m/z 173. Crude product was 95% pure based on GC-MS.

Step 3: (S)-2-Methyl-1,3-propanediol Mono THP Ether Tosylate. Crude product from step 2 (190 mMol) was added to 250 ml dry pyridine and chilled to 0°C before adding *p*-toluene sulfonyl chloride (250 mMol). It was kept overnight in a refrigerator and then poured into iced-water and extracted with ether. Ether solution was washed with water, CuSO_4 solution, NaHCO_3 solution and brine, dried over Na_2SO_4 and concentrated to give 46 g of crude product (76% pure by GC-MS) for a 57% yield. IR: absence of 3,450 cm^{-1} (w), alcohol; 1,610, 1,365, 1,195, 1,180, 1,040, 980, 820, 670 tosylate pattern. Mass spectra show the expected fragmentation pattern for pyranyl and tosylate groups [m/z 85 (base, pyran fragment), 91, 101 (pyran-ether fragment), 155, 173, and 227 (M-101)].

Step 4: (R) 2-Methyl-1-butanol THP Ether. Crude product from step 3 (132 mMol) was stirred into 200 ml of dry tetrahydrofuran and cooled to -75°C under argon. Methylmagnesium bromide (3 molar in ether, 403 mMol) was carefully added dropwise over 2 h, followed by a dropwise addition of dilithium tetrachlorocuprate solution (0.1 M in THF, using 1.24 mMol). This was then allowed to warm to 0°C and stirred at 0°C for 24–40 h. The reaction was main-

Table 1. Mean \pm SE numbers of wasps captured in traps baited with test chemicals

Chemical	<i>V. germanica</i>	<i>V. pensylvanica</i>	<i>P. aurifer</i>
Control ^a	4.1 \pm 0.8a	8.4 \pm 2.2a	1.8 \pm .8ab
3-methyl-1-butanol	12.4 \pm 2.7b	16.3 \pm 3.2bc	1.1 \pm 0.5a
Pentanol	15.8 \pm 4.2bc	11.9 \pm 2.4a	1.7 \pm 0.4ab
Butanol	16.6 \pm 3.8bc	19.8 \pm 2.9cd	1.5 \pm 0.6ab
Isopropanol	22.8 \pm 4.2c	17.5 \pm 3.5bcd	1.6 \pm 0.5ab
2-methyl-2-propanol	38.3 \pm 4.5d	26.4 \pm 4.4d	2.5 \pm 0.6b
S-(–)-2-methyl-1-butanol	52.8 \pm 10.0e	47.4 \pm 5.5e	2.6 \pm 0.8b
Isobutanol	67.6 \pm 14.9e	57.9 \pm 8.3e	2.3 \pm 0.8b
Total wasps captured	2,844	2,564	190

For a species, means followed by the same letter are not significantly different by LSD, $P \leq 0.05$. All treatments included 0.5% acetic acid in the drowning solution. First experimental series, August–September 1997, Moxee, WA.

^a Control traps include a polyethylene cap that is empty.

tained at 0°C before quenching by dropwise addition of saturated aqueous ammonium chloride. It was poured into the saturated NH_4Cl solution and extracted with hexane. Combined hexane extracts were washed with water, Na_2HCO_3 brine, and dried on Na_2SO_4 . Solvent was removed and crude product was chromatographed on silica gel, eluting with 10% ether in pentane. The product was then concentrated in vacuo, giving a yield of 74% (16 g, 86% pure by GC-MS). IR: absence of tosylate bands; presence of typical pyranyl ether pattern from 1,470 to 1,250 cm^{-1} ; 2,900–3,000 cm^{-1} , C-H stretch. Mass spectra confirmed the structure: m/z 171 [M-1], 85 [base, pyran fragment].

Step 5: (R)-2-Methyl-1-butanol. A solution of 19 g (R)-2-methyl-1-butanol THP ether from step 4 (110 mMol) in 500 ml methanol was mixed with a catalytic amount (0.11 gm) of *p*-toluenesulfonic acid monohydrate and refluxed overnight. It was neutralized with potassium carbonate, poured into brine and extracted with ether. Ether extracts were dried over Na_2SO_4 and concentrated by distillation before silica gel chromatography. Product was eluted in 50% ether/pentane and concentrated by distillation. Yields varied substantially, from 41% (4 g) to 99% (9.6 g). IR: 3,400 cm^{-1} , alcohol; 2,900–3,010 (C-H stretch), 1,470 and 1,380 (methyl), 1,060 and 1,025 (C-O stretch) cm^{-1} . Mass spectra confirmed an alcohol structure: m/z 88 (M+), 57 (base), 56, 41, and 70 (M-18). Final product (R-2-methyl-1-butanol) was determined to be 85% pure overall and $> 99\%$ enantiomerically pure, by GC analysis using a chiral Cyclosil-B column as described above.

Results

In the first experiment, the greatest numbers of workers of *V. germanica* and *V. pensylvanica* were captured in traps baited with isobutanol with acetic acid, and with S-(–)-2-methyl-1-butanol with acetic acid, compared with all other treatments (Table 1). Also, the combinations of acetic acid and butanol, 3-methyl-1-butanol, isopropanol, and 2-methyl-2-pro-

panol, were significantly more attractive to both *V. germanica* and *V. pensylvanica* than was acetic acid alone. The combination of pentanol with acetic acid was also significantly more attractive to *V. germanica* compared with acetic acid alone. Numerically greater, but not statistically significant numbers (in comparison to the control) of *P. aurifer* were captured in traps baited with acetic acid and either 2-methyl-2-propanol, S-(−)-2-methyl-1-butanol, or isobutanol compared with acetic acid alone (Table 1).

In the second experiment, the greatest numbers of both species of yellowjackets were in traps baited with isobutanol and acetic acid and with racemic 2-methyl-1-butanol and acetic acid (Table 2). Both 2-methyl-1-butanol and isobutanol were significantly better as a co-attractant for both species of yellowjackets than were the remainder of the treatments, excepting 2-methyl-1-pentanol for *V. pensylvanica*. Numbers of *P. aurifer* captured in this experiment were not suitable for statistical analysis.

In the third experiment, the greatest numbers of all three species of wasps were in traps baited with isobutanol and acetic acid (Table 3). Also of interest were the captures of *P. aurifer*, *V. germanica*, and *V. pensylvanica* wasps in traps baited with 3-methyl-2-pentanol and acetic acid, which were significantly greater than traps baited with acetic acid alone (control) as well as several other treatments (Table 3).

In the fourth experiment, *V. germanica* responded significantly to the R-(+)- enantiomer, the S-(−)- enantiomer, and the racemic mixture of 2-methyl-1-butanol when presented in traps along with an acetic acid solution (Table 4), compared with acetic acid alone. However, numbers of *V. germanica* captured in traps baited with the racemic mixture of 2-methyl-1-butanol were significantly greater than numbers captured in traps baited with the R-(+)- enantiomer and were numerically but not statistically higher than the numbers of *V. germanica* captured in traps baited with the S-(−)- enantiomer (Table 4). Numbers of *V. pensylvanica* captured in traps including either enantiomer or the racemic mixture of 2-methyl-1-butanol were significantly greater than in traps baited with

acetic acid alone. Additionally, numbers of *V. pensylvanica* in traps that included the racemic mixture of 2-methyl-1-butanol were significantly greater than numbers of *V. pensylvanica* in traps including the R-(+)- enantiomer (Table 4). Numbers of *P. aurifer* captured in traps baited with racemic or S-(−)-2-methyl-1-butanol and acetic acid were significantly greater than in traps baited with acetic acid alone or with the R-(+)- enantiomer plus acetic acid (Table 4).

Discussion

The principle objective of this study was to determine what compounds similar in structure to isobutanol are similarly effective as co-attractants for social wasps when presented in traps with acetic acid (Landolt 1998a, 1998b; Landolt et al. 1999). A number of compounds tested here showed some co-attractiveness with acetic acid for both species of *Vespa*, or for *P. aurifer*, as indicated by captures of wasps in baited traps. However, only racemic or S-(−)-2-methyl-1-butanol appeared to be comparable to isobutanol as a co-attractant for *V. germanica* or *V. pensylvanica*. S-(−)-2-methyl-1-butanol was also found to be a strong co-attractant for *P. aurifer*. 2-Methyl-1-butanol was tested both as a racemic mixture in test 2, as the S-(−)- enantiomer in test 1, and as the R-(+)- and S-(−) enantiomers in test 4. Although both enantiomers were highly co-attractive with acetic acid for yellowjackets, neither was superior to isobutanol.

2-Methyl-1-butanol is another compound (after isobutanol) that is a good co-attractant for the *V. germanica* and *V. pensylvanica* and *P. aurifer* and should be considered in further efforts to develop lures and baits for these and possibly other species of social wasps.

Additional compounds of interest are 2-methyl-2-propanol, 2-methyl-2-butanol, and 3-methyl-2-pentanol. Although not comparable to isobutanol as co-attractants with acetic acid for social wasps, they both were superior to most other compounds tested as co-attractants for one or more of the three species of Vespidae responding in this study. These chemicals may be worth considering for further evaluation, ei-

Table 2. Mean \pm SE numbers of wasps captured in traps baited with test chemicals

Chemical	<i>V. germanica</i>	<i>V. pensylvanica</i>
Control ^a	0.1 \pm 0.1a	1.1 \pm 0.8a
2-methyl-2-pentanol	3.2 \pm 1.9ab	0.7 \pm 0.6a
2-butanol	3.8 \pm 2.8abc	0.8 \pm 0.5a
2-methyl-1-pentanol	8.2 \pm 2.1bc	4.9 \pm 2.2bc
Neopentyl alcohol	9.7 \pm 4.2bc	2.0 \pm 1.0a
3-methyl-2-butanol	10.0 \pm 3.8bc	2.2 \pm 1.0ab
2-methyl-2-butanol	14.4 \pm 5.7c	3.0 \pm 1.5ab
RS 2-methyl-1-butanol	47.9 \pm 35.1d	6.3 \pm 1.3c
Isobutanol	35.1 \pm 9.1d	9.6 \pm 3.6c
Total wasps captured	1,192	275

For a species, means followed by the same letter are not significantly different by LSD, $P \leq 0.05$. All treatments included 0.5% acetic acid in the drowning solution. Second experimental series, October 1997, Moxee, WA. Numbers of *P. aurifer* overall were too low for analysis.

^aControl traps included a polyethylene cap that was not loaded.

Table 3. Mean \pm SE numbers of wasps captured in traps baited with test chemicals

Chemical	<i>V. germanica</i>	<i>V. pensylvanica</i>	<i>P. aurifer</i>
Control ^a	0.8 \pm 0.4a	0.8 \pm 0.4a	0.8 \pm 0.3a
2-pentanol	1.6 \pm 0.5a	3.4 \pm 0.9bc	1.9 \pm 0.5bc
3-methyl-1-pentanol	3.6 \pm 1.3b	5.4 \pm 1.8cd	2.1 \pm 0.5bcd
3-methyl-2-pentanol	6.9 \pm 1.3c	9.1 \pm 2.3de	3.5 \pm 0.8de
3-methyl-3-pentanol	3.4 \pm 0.7b	6.1 \pm 1.2d	2.5 \pm 0.9bcd
4-methyl-1-pentanol	1.8 \pm 0.6a	3.1 \pm 1.8c	2.8 \pm 0.8cde
4-methyl-2-pentanol	0.9 \pm 0.3a	1.9 \pm 0.7b	1.5 \pm 0.5ab
Isobutanol	11.1 \pm 1.8d	15.9 \pm 3.6e	4.6 \pm 1.0e
Total wasps captured	451	669	322

For a species, means followed by the same letter are not significantly different by LSD, $P \leq 0.05$. All treatments included 0.5% acetic acid in the drowning solution. Third experimental series, July–August 1998, Moxee, WA.

^aControl traps included a polyethylene cap that was not loaded.

Table 4. Mean \pm SE numbers of *V. germanica* and *V. pensylvanica* and *P. aurifer* captured with enantiomers of 2-methyl-1-butanol tested in traps with 0.5% acetic acid in the trap drowning solution, August–September 1998, Moxee, WA

Chemical	<i>V. germanica</i>	<i>V. pensylvanica</i>	<i>P. aurifer</i>
Control	0.3 \pm 0.1a	5.0 \pm 1.4a	2.3 \pm 0.4a
R-(+)-2-methyl-1-butanol	3.8 \pm 0.7b	18.5 \pm 2.5b	2.2 \pm 0.5a
S-(–)-2-methyl-1-butanol	5.5 \pm 1.0bc	22.8 \pm 3.0bc	3.7 \pm 0.7b
RS 2-methyl-1-butanol	6.9 \pm 0.9c	30.2 \pm 5.7c	4.5 \pm 0.7b
Total wasps captured	396	1,835	305

For a species, means followed by the same letter are not significantly different by LSD, $P \leq 0.05$.

ther over a range of release rates or for different species of social wasps that do not respond well to isobutanol.

Both yellowjacket species responded similarly to the compounds tested in all experiments; e.g., those chemicals performing well for *V. germanica* generally performed well for *V. pensylvanica* and those compounds performing the poorest for one were also the poorest for the other. This similarity in response provides the opportunity to trap both pestiferous species with the same lures. It is not known how other social wasp species in other geographic areas may respond to these same compounds. However, Landolt et al. (1999) and Day and Jeanne (2001) found that some other pestiferous yellowjackets, hornets, and paper wasps are attracted to the combination of acetic acid and isobutanol. Also of interest is a possible lack of response by certain species such as *V. atropilosa* (Sladen) and *Dolichovespula arenaria* (F.), which were expected to occur at some sites but were not trapped in significant numbers (herein, Landolt et al. 1999, Day and Jeanne 2001).

Recent research by several laboratories has documented broad olfactory capabilities of yellowjackets; they are able to detect and respond to odors of carbohydrate baits (Spurr 1996; Jander 1998; Landolt 1998a, 1998b), protein baits (Ross et al. 1984, Spurr 1995), fruit and plant volatiles (Day and Jeanne 2001), and various insect prey (Aldrich et al. 1985, 1986; Hendrichs and Hendrichs 1998), and some species are able to learn odors (Jander 1998) and communicate to nestmates via odor cues (Overmyer and Jeanne 1998). This diversity in food-finding behavior by social wasps suggests a great potential for people to monitor, manage, and control pestiferous yellowjackets and paper wasps in different geographic areas with odor-based trapping systems.

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